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SAMPLE CHECKING DEVICE

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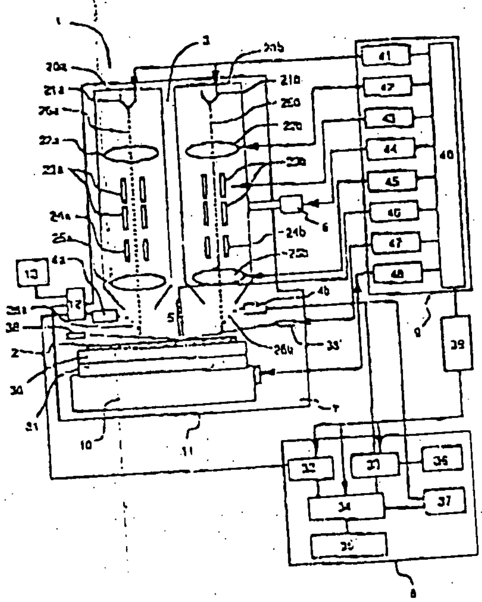
Abstract

Objective

To check samples with repeated patterns for defects, foreign matter, residue, etc., at high speed with electron beams.

Constitution

Various patterns on sample (2) are checked with electron beams (26a) and (26b) obtained from electron beam systems (20a) and (20b), which simultaneously irradiate areas of the sample where repeated patterns are formed. Depending on a blocking electrode arranged between said two electron beam systems (20a) and (20b), the electrons generated from each irradiated part are detected independently, and the obtained image signals are compared.



Claims

1. A sample checking device comprised of an electron beam system which has multiple groups of electron beam irradiating means for irradiating electron beams on the surface of the sample and detectors for detecting the electrons generated by irradiation of the aforementioned electron beams, a sample stage which is used to hold the aforementioned sample and can move continuously at least in one direction during the period when the aforementioned electron beams are irradiated on the sample, blocking electrodes which are arranged between the aforementioned electron beam irradiating means, and a calculating means which compares the signals obtained from the aforementioned detectors to detect the defects on the aforementioned sample.

2. A sample checking device comprised of the following parts: an electron beam system which is comprised of a first electron beam irradiating means for irradiating a first electron beam on the surface of the sample, a first detector for detecting the electrons generated by irradiation of the aforementioned electron beam, a second electron beam irradiating means for irradiating a second electron beam in a region on the aforementioned surface of the sample different from the

region irradiated by the first electron beam, and a second detector for detecting the electrons generated by irradiation of the electron beam; a sample stage which is used to hold the aforementioned sample and can move continuously at least in one direction during the period when the aforementioned first and second electron beams are irradiated; a blocking electrode which is arranged between the aforementioned first and second electron beam irradiating means; a signal processing means which can convert the signals obtained from the first and second detectors to the image signals of the regions irradiated by the first and second electron beams; and a calculating means which compares the image signals obtained from the first and second detectors to detect the defects on the aforementioned sample.

3. The sample checking device described in Claim 1 or 2 characterized by the fact that the aforementioned electron beam irradiating means is at least comprised of a diffusion supply type thermoelectron-emitting electron gun, an electrostatic objective lens, and a scanner which can scan the aforementioned electron beams in the desired region on the aforementioned sample.

4. The sample checking device described in any of Claims 1-3 characterized by the fact that the aforementioned blocking electrode is connected to a variable voltage power supply with a negative voltage output.

5. The sample checking device described in any of Claims 1-4 characterized by the fact that it includes an optical axis adjustment means which can adjust the intervals between the optical axes of the aforementioned electron beam irradiating means and is able to keep the optical axes parallel to each other and perpendicular to the aforementioned sample.

6. The sample checking device described in any of Claims 1-5 characterized by the fact that the aforementioned sample is a semiconductor wafer, photomask, semiconductor device, or magnetic head substrate on which repeated patterns are formed.

7. The sample checking device described in any of Claims 1-6 characterized by the fact that the electron guns of the aforementioned electron beam irradiating means are connected to the same accelerating power supply.

8. The sample checking device described in any of Claims 1-7 characterized by having an optical microscope for observing the positions of the patterns formed on the aforementioned sample.

9. The sample checking device described in any of Claims 1-8 characterized by the fact that the aforementioned electron beam irradiating means are installed in different vacuum chambers which can be independently evacuated.

10. A magnetic head checking device characterized by the fact that the device uses electron beams to check the shapes of magnetic heads which are formed repeatedly on a substrate, and the device is comprised of an electron beam system which has multiple groups of electron beam irradiating means for irradiating electron beams on the surface of the substrate and

detectors for detecting the electrons generated from the irradiated regions, a sample stage which is used to hold the aforementioned substrate and can move continuously at least in one direction during the period when the aforementioned electron beams are irradiated on the substrate, blocking electrodes which are arranged between the aforementioned electron beam irradiating means, a signal processing means which can convert the signals obtained from the aforementioned detectors to the image signals of the regions irradiated by the aforementioned electron beams, and a calculating means which compares the signals obtained from the aforementioned detectors for detection of defects on the aforementioned sample.

11. The magnetic head checking device described in Claim 10 characterized by the fact that the aforementioned substrate is a strip substrate on which an array of magnetic heads are formed, and the substrates are arranged in such a way that the points of intersection on the aforementioned sample stage, where the aforementioned multiple strip substrates are arranged parallel to each other and the optical axes of the aforementioned electron beam irradiating means are on the same straight line which is perpendicular to the aforementioned strip samples.

12. A sample processing device characterized by the fact that the device is used to process part of a sample substrate and at least has a first ion beam irradiating device which irradiates a first ion beam on the sample substrate where repeated patterns are formed, a first secondary ion detector which can detect the secondary ions generated from the aforementioned sample by irradiation of the ion beam, a second ion beam irradiating means which irradiates a second ion beam on a pattern different from the pattern irradiated by the first ion beam on the sample substrate, a second secondary electron detector which can detect the secondary electrons generated from the aforementioned sample by irradiation of the ion beam, a secondary electron blocking electrode which is arranged between the aforementioned first and second ion beam irradiating means, and a sample stage which is used to hold the aforementioned sample substrate and can move continuously at least in one direction during the period when the aforementioned sample substrate is irradiated with the first and second ion beams.

13. The sample processing device described in Claim 12 characterized by the fact that the aforementioned ion beams are focused ion beams.

14. The sample processing device described in Claim 12 characterized by the fact that the aforementioned sample substrate is a semiconductor wafer, photomask, semiconductor device, or magnetic head substrate.

15. A sample checking method characterized by the following facts: among the patterns which are formed repeatedly on a sample substrate, different patterns are observed simultaneously with a first and a second electron beam; the defects in the aforementioned patterns are checked by comparing the obtained pattern images; the electrons generated by the irradiation with the aforementioned first and second electron beams are detected separately

depending on an blocking electrode arranged between the first and second electron beams and then converted into pattern images which are compared with each other.

16. The sample checking method described in Claim 15 characterized by the fact that the voltage applied to the aforementioned blocking electrode can be any voltage in the range of -1 V to -50 V with respect to the aforementioned sample substrate.

17. The sample checking method described in Claim 15 or 16 characterized by including a step in which a special part is selected from the pattern image obtained using one of the electron beams, and the position of the pattern image is corrected so that the selected part is consistent with the same part of the other pattern image.

18. The sample checking method described in Claim 15 or 16 characterized by including a step in which the positions of two particular spots are selected from the pattern image obtained using one of the electron beams, and the magnification is corrected so that the positions of the two selected spots are consistent with the positions of the same two spots in other pattern image.

19. The sample checking method described in Claim 15 or 16 characterized by including a step in which a defect-free pattern is stored as reference data before the checking and is compared with the pattern images obtained by irradiation with the first and second electron beams to detect defects.

20. The sample checking method described in Claim 15 or 16 characterized by including a step which is carried out as follows: the aforementioned first and second electron beams are irradiated on two different well-known patterns before the desired sample checking, respectively; the voltage applied to the aforementioned blocking electrode is changed while the obtained patterns are detected; and the aforementioned blocking voltage is set in such a way that the obtained pattern images are separated into the aforementioned two different well-known patterns.

21. The sample checking method described in Claim 15 characterized by including a step in which the interval between the optical axes of the first and second electron beam systems is set to be an integral number of times the width of the aforementioned repeated patterns before the desired sample checking.

22. The sample checking method described in Claim 15 characterized by including a step in which the magnification and/or position are corrected before the desired sample checking in such a way that the images obtained using the first and second electron beams are in the same field of view.

23. The sample checking method described in Claim 15 characterized by including a step in which the angular position of the sample stage is corrected before sample checking by making the straight line that passes through the two spots irradiated by the undeflected first and second electron beams parallel to one side of the perimeter of the aforementioned pattern.

24. The sample checking method described in Claim 15 characterized by being carried out along with a processing step in which the aforementioned detected defective regions are corrected with focused ion beams.

25. A sample processing method characterized by the following facts: the method is used to process a part of each of the patterns formed repeatedly on a sample substrate by irradiating a first and second ion beam on different patterns; and the method has a step in which the secondary electrons generated by irradiation of the aforementioned first and second ion beams are detected separately depending on a blocking electrode arranged between the first and second ion beams, and the aforementioned patterns are observed simultaneously.

26. The sample processing method described in Claim 25 characterized by the fact that the aforementioned sample substrate is a magnetic head substrate, and the aforementioned first and second ion beams are used to trim a part of the aforementioned magnetic head substrate simultaneously.

Detailed explanation of the invention

[0001]

Industrial application field

The present invention pertains to sample checking method and device which can use electron beams to check for defects on a sample at high speed with high sensitivity and high resolution.

[0002]

Prior art

A device which can optically compare and check the images of two or more LSI patterns of the same type on a wafer has been put into practical application as a sample checking method for comparing detecting defects in the circuit patterns formed on a semiconductor device or wafer. A summary of this inspection method can be found in "Semiconductor World," August 1995, pp. 114-117 (Conventional Example 10). When the defects in the patterns are checked using the aforementioned optical inspection method in a semiconductor device manufacturing process, the residues of the photosensitive resist material or the silicon oxide film through which light is transmitted cannot be detected. Also, the presence of etching residues, improperly formed through-holes, and other defects below the resolution limit of the optical system cannot be detected.

[0003]

To solve these problems, a type of device using an electron beam to compare patterns is disclosed in the following references: Japanese Kokai Patent Application No. Sho 59[1984]-192943 (Conventional Example 1), "Journal of Vacuum Science and Technology," Vol. B9 (1991), pp. 3005-3009 (Conventional Example 2), SPIE (The Society of Photo-optical Instrumentation Engineers), Vol. 2439 (1995), pp. 174-183 (Conventional Example 3), and Japanese Kokai Patent Application No. Hei 5[1993]-258703 (Conventional Example 4). In this case, to obtain a practical inspection speed, it is necessary to obtain images at very high speed. To guarantee a good S/N (signal to noise ratio) for the images obtained at high speed, an electron beam with a current (10 nA or more), which is more than 100 times greater than that used in a normal scanning electron microscope, is required.

[0004]

Japanese Kokai Patent Application No. Sho 59[1984]-6537 (Conventional Example 5) disclosed a comparison checking method which uses two electron beams. The present method uses a defect checking device equipped with two groups of electron beam irradiating means, which irradiate electron beams on two patterns at the same place among the pattern group which is arranged regularly on the same substrate, and two groups of sensors which are arranged corresponding to the aforementioned two electron beam irradiating means and can detect the electron beams modulated by the aforementioned patterns. The difference signal between the two sensors is recognized as a defect.

[0005]

Similar technologies are also disclosed in Japanese Kokai Patent Application Nos. Sho 62[1987]-137835 (Conventional Example 6), Hei 4[1992]-51441 (Conventional Example 7), and Hei 4[1992]-361544 (Conventional Example 8).

[0006]

Problems to be solved by the invention

A sample checking device must have high checking speed and high checking accuracy (that is, resolution). To realize high-speed checking, in the technologies disclosed in said Conventional Examples 1-5, it is necessary to increase the electron beam current and to form images with a S/N that guarantees detection. However, in order to focus an electron beam to a spot and scan it over a plane, there is a limit to how much the checking time can be reduced. For example, the intensity of the electron gun is limited, and there is a limit to how high the current density of an electron beam can be increased since it depends on the space charge effect. For

instance, even when a resolution of about 0.1 μm is obtained, the actual electron beam current is only about 100 nA although the theoretical limit is several hundred nA. The S/N of an image is a function of the product of the number of electrons used for forming the image, that is, the current, and the time needed for obtaining the image. When the S/N is maintained on a level capable of image processing and a resolution of 0.1 μm is obtained at a current value of 100 nA, about 100 sec or more are needed to check an area of 1 cm^2. On the other hand, when the aforementioned optical checking device is used, an area of 1 cm^2 can be checked in about 5 sec. Consequently, it is impossible to realize both high resolution and high-speed checking with the conventional sample checking device since it is an electron-beam-based system.

[0007]

The checking method disclosed in Conventional Example 5 and using two electron beams or another checking method using multiple electron beams can shorten the checking time and realize high-speed checking. However, the following problem occurs when multiple electron beams are irradiated simultaneously.

[0008]

For example, Figure 2 shows the paths of the secondary electrons generated by the irradiation of two electron beams to the detectors. The secondary electrons (28a) generated by the irradiation of the first electron beam (25a) fly toward detector (4a). The secondary electrons (28b) generated by the irradiation of the second electron beam (25b) fly toward detector (4b). However, some secondary electrons (28'b) also fly toward detector (4a). The secondary electrons generated by electron beam (25a) create the same problem: some secondary electrons (28') fly toward detector (4b).

[0009]

For example, a pattern (51) is present in the scanning region (50a) of electron beam (25a) with the original surface shape shown in Figure 3(a). On the other hand, a pattern (52) is present in the scanning region of electron beam (25b) with the shape shown in Figure 3(b) (secondary electron image). When electron beams (25a) and (25b) are irradiated at different times, the secondary electron images shown in Figures 3(a) and 3(b) can be obtained separately. However, when the electron beams are irradiated simultaneously, since secondary electrons fly into the other detector as shown in Figure 2, the secondary electron image obtained by detector (4a) will appear like the one shown in Figure 3(c), while the secondary electron image obtained by detector (4b) will be like the one shown in Figure 3(d) under simultaneous irradiation. The shapes of these secondary electron images are different from the original shapes shown in

Figures 3(a) and 3(b). Consequently, it is impossible to realize the original purpose, that is, to compare patterns in two irradiation regions with electron beams (25a) and (25b).

[0010]

Said Conventional Example 6 discloses an observation method which uses two beam systems. However, the two beams cannot be irradiated simultaneously on two patterns because the secondary electron signals generated from the two patterns will interfere. The beams are irradiated under time division, and the secondary electrons are detected with one detector under time division.

[0011]

Conventional Example 7 discloses a device used for observing the three-dimensional shape of a sample by irradiating electron beams from multiple electron guns under time division or by moving one electron beam source in a space to perform sequential irradiation. The conventional example also discloses an observation method using two beam systems. In this method, however, the beams are irradiated under time division, and the secondary electrons are detected under time division. Nevertheless, in this method, the time required for checking two patterns is the same as the time required for checking two patterns one by one even if irradiation and detection are performed under time division. Therefore, the checking time cannot be shortened.

[0012]

When two electron beams are irradiated simultaneously, since the diameter of a magnetic lens using an electromagnetic coil in the conventional method is in the range of 100-150 mm, the overall size of the electron beam irradiating system cannot be reduced. It is difficult to arrange two groups of electro-optical systems side by side. For example, it is impossible to simultaneously observe two device chip patterns which are arranged at an interval of 10 mm on a wafer with a diameter of 200 mm.

[0013]

Also, since said Conventional Example 6 does not say anything about adjusting the interval between the electron beams corresponding to the dimension of the pattern on the sample, it cannot be used in the case when the widths of the patterns on the sample are different, for example, when checking different types of device chips.

[0014]

In Conventional Example 8, multiple electron beams are used to perform the inspection. However, since the electron guns (electron emitters) are fixed in position in the equipment, the interval between electron beams, that is, the spacing between electron guns cannot be adjusted to correspond to the dimensions of the patterns on the sample. The present conventional example discloses a means for driving the electron beam generating means. The driving means, however, moves the electron guns simultaneously. As a result, it is impossible to individually adjust the intervals between the electron guns. A method with which the intervals between the optical axes of electron beams can be adjusted is required to develop a popular sample checking device which can compare patterns of various dimensions.

[0015]

In order to solve the aforementioned problems, one purpose of the present invention is to provide a sample checking device which can compare and check the defects on a sample, such as a semiconductor wafer, semiconductor device, or magnetic device, by irradiating multiple beams simultaneously and can shorten the inspection time by independently collecting the electrons generated from the parts irradiated with the beams and to provide a sample checking method realized by using the aforementioned sample checking device. Another purpose of the present invention is to provide a magnetic head checking device by limiting the application range of the aforementioned sample checking device. Yet another purpose of the present invention is to provide a sample processing device which can process samples simultaneously by irradiating multiple beams simultaneously on the samples.

[0016]

Means for solving the problems

In order to realize the aforementioned purposes, the present invention provides a sample checking device comprised of an electron beam system which has multiple groups of electron beam irradiating means for irradiating electron beams on a surface of the sample and detectors for detecting the electrons generated by irradiation of the aforementioned electron beams, a sample stage which is used to hold the aforementioned sample and can move continuously at least in one direction during the period when the aforementioned electron beams irradiate the sample, blocking electrodes which are arranged between the aforementioned electron beam irradiating means, and a calculating means which compares the signals obtained from the aforementioned detectors to detect the defects on the aforementioned sample.

[0017]

The most simplified sample checking device using multiple electron beams is comprised of the following parts: an electron beam system which is comprised of a first electron beam irradiating means for irradiating a surface of the sample with a first electron beam, a first detector for detecting the electrons generated by irradiation of the aforementioned electron beam, a second electron beam irradiating means for irradiating a second electron beam in a region on the aforementioned surface of the sample, which is different than the region irradiated by the first electron beam, and a second detector for detecting the electrons generated by irradiation with the electron beam; a sample stage which is used to hold the aforementioned sample and can move continuously at least in one direction during the period when the aforementioned first and second electron beams are irradiated; a blocking electrode which is arranged between the aforementioned first and second electron beam irradiating means; a signal processing means which can convert the signals obtained from the first and second detectors into the image signals of the regions irradiated by the first and second electron beams; and a calculating means which compares the image signals obtained from the first and second detectors to detect the defects on the aforementioned sample.

[0018]

In these sample checking devices, the electron beam irradiating means is at least comprised of a diffusion supply type thermoelectron-emitting electron gun, an electrostatic objective lens, and a scanner which can scan the aforementioned electron beams in a desired region on the aforementioned sample. In this way, electron beams with a high current density can be obtained, and the optical system can be miniaturized, making it possible to use multiple electron beam irradiating means at the same time. Also, since the blocking electrode is connected to a variable voltage power supply with a negative voltage output, the reflected electrons or secondary electrons generated from the parts irradiated with the electron beams can be collected independently. In addition, the electron beam system has an optical axis adjusting means which can adjust the intervals between the optical axes of the aforementioned electron beam irradiating means and is able to make the optical axes parallel to each other and perpendicular to the aforementioned sample. In this way, the position of each optical axis can be adjusted corresponding to the width of the repeated patterns on the sample.

[0019]

Examples of the samples that can be used include semiconductor wafers, photomasks, semiconductor devices, magnetic head substrates, etc., on which repeated patterns are formed. The electron guns in the electron beam irradiating means are connected to the same power

supply for acceleration. In this way, multiple electrons can be generated by a small number of power supplies. The characteristics and scanning conditions can be uniformized by supplying the voltage from the same power supply not only to the electron guns but also to the lenses or deflectors.

[0020]

An optical microscope used for observing the positions of the patterns formed on the sample is arranged in the sample chamber. In this way, rotary correction of the sample substrate and approximate adjustment on the target position can be performed before the checking so that deviation in the positions of the patterns can be prevented during the checking. It is also possible to install the electron beam irradiating means in different vacuum chambers which can be evacuated separately. In this way, even if a problem occurs with one electron gun, the electron beam irradiating means can be moved to a different atmosphere than that of the sample chamber so that the electron gun can be repaired. More specifically, each electron beam irradiating means is installed in a housing, and an independent evaluation system is arranged in each of the housings. A gate valve is arranged on the electrode in the final stage of the objective lens.

[0021]

Another embodiment of the sample checking device is a magnetic head checking device which uses electron beams to check the shapes of magnetic heads arranged repeatedly on a substrate. The aforementioned problems can also be solved by a magnetic head checking device comprised of an electron beam system which has multiple groups of electron beam irradiating means for irradiating electron beams on the surface of the substrate and detectors for detecting the electrons generated from the irradiated regions, a sample stage which is used to hold the aforementioned substrate and can move continuously at least in one direction during the period when the aforementioned electron beams are irradiated on the substrate, blocking electrodes which are arranged between the aforementioned electron beam irradiating means, a signal processing means which can convert the signals obtained from the aforementioned detectors into image signals of the regions irradiated by the aforementioned electron beams, and a calculating means which compares the signals obtained from the aforementioned detectors to detect the defects on the aforementioned sample.

[0022]

In the aforementioned magnetic head checking device, the substrate is a strip substrate on which an array of magnetic heads are formed, and the substrates are arranged in such a way that the point of intersection of the aforementioned sample stage, where multiple said strip substrates

are arranged parallel to each other and the optical axes of the aforementioned electron beam irradiating means are on the same straight line which is perpendicular to the aforementioned strip samples.

[0023]

Yet another embodiment of the sample checking device is a sample processing device characterized by the fact that the device is used to process part of a sample substrate and at least has a first ion beam irradiating device which irradiates a first ion beam on the sample substrate where repeated patterns are formed, a first secondary ion detector which can detect the secondary ions generated from the aforementioned sample by irradiation of the ion beam, a second ion beam irradiating means which irradiates a second ion beam on a pattern different from the pattern irradiated by the first ion beam on the sample substrate, a second secondary electron detector which can detect the secondary electrons generated from the aforementioned sample by irradiation of the ion beam, a secondary electron blocking electrode which is arranged between the aforementioned first and second ion beam irradiating means, and a sample stage which is used to hold the aforementioned sample substrate and can move continuously at least in one direction during the period when the aforementioned sample substrate is irradiated with the first and second ion beams.

[0024]

In this case, fine processing can be performed if focused ion beams are used. Examples of the sample substrates that can be used include semiconductor wafers, photomasks, semiconductor devices, and magnetic head substrates. In particular, the recording tracks on a magnetic head can be trimmed with great efficiency.

[0025]

The aforementioned purposes can be realized by a sample checking method characterized by the following facts: among the patterns which are formed repeatedly on a sample substrate, different patterns are observed simultaneously with first and second electron beams; the defects in the aforementioned patterns are checked by comparing the obtained pattern images; the electrons generated by irradiation of the aforementioned first and second electron beams are detected separately depending on a blocking electrode arranged between the first and second electron beams and then converted into pattern images which are compared.

[0026]

In this case, the voltage applied to the aforementioned blocking electrode can be any voltage in the range of -1 V to -50 V with respect to the aforementioned sample substrate. The sample checking method may include a step in which a special part is selected from the pattern image obtained using one of the electron beams, and the position of the pattern image is corrected so that the selected part is consistent with the same part of the other pattern image.

[0027]

The sample checking method may also include a step in which the positions of two particular spots are selected from the pattern image obtained using one of the electron beams, and the magnification is corrected so that the positions of the two selected spots are consistent with the positions of the same two spots in other pattern image.

[0028]

The sample checking method may also include a step in which a defect-free pattern is stored as reference data before the checking for comparison with the pattern images obtained by irradiation of the first and second electron beams to detect defects.

[0029]

The sample checking method may also include a step which is carried out as follows: the aforementioned first and second electron beams are irradiated on two different well-known patterns before the desired sample checking, respectively; the voltage applied to the aforementioned blocking electrode is changed while the obtained patterns are detected; and the aforementioned blocking voltage is set in such a way that the obtained pattern images are separated into the aforementioned two different well-known patterns.

[0030]

The sample checking method may also include a step in which the interval between the optical axes of the first and second electron beam systems is set to be an integral number of times the width of the aforementioned repeated patterns before the desired sample checking.

[0031]

The sample checking method may also include a step in which the magnification and/or position are corrected before the desired sample checking in such a way that the images obtained using the first and second electron beams are in the same field of view. The sample checking method may also include a step in which the angular position of the sample stage is corrected

before sample inspection by making the straight line that passes through the two spots irradiated by the undeflected first and second electron beams parallel to one side of the perimeter of the aforementioned pattern.

[0032]

The sample checking method can be carried out along with a processing step in which the aforementioned detected defective regions are corrected with focused ion beams. It is also possible to realize the aforementioned purposes using another sample processing method characterized by the following facts: the method is used to process a part of each of the patterns formed repeatedly on a sample substrate by irradiating a first and second ion beam on different patterns; and the method has a step in which the secondary electrons generated by irradiation of the aforementioned first and second ion beams are detected separately depending on a blocking electrode arranged between the first and second ion beams, and the aforementioned patterns are observed simultaneously. In particular, if the aforementioned sample substrate is a magnetic head substrate, the magnetic head can be processed at high speed when the aforementioned first and second ion beams are used to trim a part of the aforementioned magnetic head substrate simultaneously.

[0033]

When the aforementioned sample checking method is carried out along with a processing step in which the detected defective regions are corrected with focused ion beams, the defective samples can be corrected in a short period of time, and the manufacturing yield can be improved.

[0034]

Embodiment of the present invention

The sample checking device of the present invention is used to find defects, etc. of the patterns formed repeatedly on a sample substrate, such as a semiconductor wafer, depending on the pattern images obtained by irradiating multiple electron beams on different patterns on the sample substrate and independently checking the secondary electrons or reflected ions generated from the irradiated regions. As shown in Figure 1, the sample checking device is comprised of electron beam system (3), secondary electron detector (4), blocking electrode (5), optical axis interval adjusting means (6), sample chamber (7), image processing unit (8), control unit (9), etc. Said electron beam system (3), secondary electron detector (4), blocking electrode (5), and sample stage (10) are arranged in vacuum chamber (11). Multiple electron beams (26a) and (26b) are irradiated simultaneously. The electrons generated by the irradiated parts are collected independently with the aid of the blocking electrode and are converted into pattern image

signals. The image signals are compared to detect the defective parts. The comparison checking can be carried out by repeating the aforementioned operation over the entire sample.

[0035]

Application Example 1

The schematic configuration of an application example of the sample checking device disclosed in the present invention will be explained with reference to Figure 1.

[0036]

In sample checking device (1) disclosed in Application Example 1, electron beam system (3) has two electron beam irradiating means (20a) and (20b) which are comprised of electron guns (21a) and (21b), condenser lenses (22a) and (22b), scanning deflectors (23a) and (23b), deflectors (24a) and (24b) for blanking, as well as electrostatic objective lenses (25a) and (25b). Extracting electrodes, diaphragms, and other parts of the electron beam system are omitted from the figure.

[0037]

Secondary electron detectors (4a) and (4b) are arranged in electron beam irradiating means (20a) and (20b), respectively. In the present application example, said secondary electron detectors (4a) and (4b) are arranged between sample (2) and electrostatic objective lenses (25a), (25b), respectively. However, the positions of the secondary electron detectors are not limited to those disclosed in the present example. Blocking electrode (5) is able to apply a low negative potential with respect to the sample potential to separate secondary electrons (28a) and (28b) or electrons reflected from the parts irradiated with said two electron beams (26a) and (26b) so that the electrons can be detected by secondary electron detectors (4a) and (4b) of the electron beam system or by reflected electron detectors.

[0038]

Said optical axis interval adjusting means (6) is used for rough adjustment of the interval between the optical axes (optical centers) of two electron beam irradiating means (20a) and (20b) according to the interval between the patterns (such as the width of the device) on the sample to be checked. In the present example, electron beam irradiating means (20a) is fixed, and optical axis interval adjusting means (6) is only installed on the other electron beam irradiating means (20b). The optical axis can be adjusted by only moving the electron beam irradiating means arranged in the vacuum chamber. When the electron beam irradiating systems are arranged in different housings, the optical axis can also be adjusted by moving each individual housing.

Sample table (10), XY stage (30), and rotary stage (31) are arranged in sample chamber (7) which is connected to optical height measuring device (47) and length measuring device (48) for position monitoring.

[0039]

Image processing unit (8) is comprised of image memory parts (32) and (33), calculating part (34), and defect evaluation unit (35). The input pattern images are displayed on monitor (36). The operating instructions and operating conditions of each part of the device are input from control unit (9). The accelerating voltage for generating the electron beams, the deflection width of the electron beams, the deflecting speed, the signal input timing of the secondary electron detectors, and other conditions are input into control unit (9) in advance. Also, control unit (9) uses a correction control circuit (40) to generate correction signals from the signals of optical height measuring device (47) and length measuring device (48) for position monitoring. The control unit sends the correction signals to objective lens power supply (45) and scanning signal generator (43) so that electron beams (26a) and (26b) can be constantly irradiated at the correct positions.

[0040]

Secondary electrons (28a) and (28b) generated at the parts irradiated with the first electron beams (26a) and (26b) are detected with detectors (4a) and (4b), respectively. The secondary electron signals detected with secondary electron detectors (4a) and (4b) are amplified, digitized, optically transmitted, and sent to image processing unit (8). In image processing unit (8), a pattern image used for comparison checking can be obtained based on the received signals. A pattern image can be obtained for the second electron beam in the same sequence. The two image signals are compared in calculating part (34) and defect evaluation unit (35) to detect the defective part. Comparative checking can be carried out by repeating the aforementioned operation over the entire sample.

[0041]

Each unit will be explained in detail below.

[0042]

Electron beam irradiating means

First, electron beam (26a) emitted from the first electron gun (21a) to which a high negative voltage is applied by accelerating voltage power supply (41) is focused on sample (2) by objective lens (25a) comprised of two electrodes. Said objective lens (25a) is an electrostatic

lens instead of a magnetic lens used for a conventional SEM. As a result, the lens can be miniaturized because there is no need to use an excitation coil as for a magnetic lens. For example, the diameter of a conventional magnetic lens is in the range of 100-150 mm. On the other hand, the diameter of the electrostatic lens can be easily reduced to 50 mm or less. Therefore, multiple electron beam irradiating means can be used together. An example of constituting a scanning electron microscope using electrostatic lenses is disclosed in Japanese Kokoku Patent No. Hei 7[1995]-1681 (Conventional Example 9).

[0043]

The irradiated region can be moved to or scanned at any position of the sample by using scanning deflectors (scanners) (24a) and (25b). A negative potential which is lower or slightly higher than that of the electron gun is applied to sample (2) by the power supply. When a potential below that on electron gun (21) is applied, the sample is checked with reflected electrons. The electrons decelerate as they approach sample (2), collide with sample (2) and are scattered by the atoms on the surface of the sample.

[0044]

Electron guns (21a) and (21b) are diffusion supply type thermoelectron-emitting electron guns. In this way, pattern images with few changes can be obtained, and the current of the electron beam can be set to a high level. As a result, high-speed checking becomes possible. Electron beams (26a) and (26b) are extracted by applying a voltage between electron guns (21a), (21b) and the extracting electrode (not shown in the figure). Electron beams (26a) and (26b) are accelerated by applying a high negative voltage to electron guns (21a) and (21b). In this way, electron beams (26a) and (26b) are transmitted toward sample (2) under the energy corresponding to the potential of the accelerating voltage, focused by condenser lens (22) and objective lens (25), and irradiated on sample (2). A negative voltage can be applied to sample (2) by a high voltage power supply (not shown in the figure). By adjusting the high voltage, it is possible to adjust the energy for irradiating the electron beams on sample (2) to the optimum level.

[0045]

Said two electron beam irradiating means (20a) and (20b) can be operated independently. However, the accelerating voltage applied to electrons guns (21a) and (21b), the condenser lens voltage, the objective lens voltage, and the voltage applied to the scanner are supplied from the same power supply to make the characteristics of the two beams uniform. Of course, the emission current value varies due to the slight difference in the characteristics of the electron

gun, and the convergence characteristic also varies due to the assembly error of the optical system. Therefore, a power supply (not shown in the figure) for fine adjustment is used for the lens voltage, deflecting voltage, and extracting voltage. Electron guns (21), sample stage (10), condenser lenses (32), objective lenses (25), scanning deflectors (24), detectors (4), and other constituent elements are accommodated in vacuum chamber (11).

[0046]

Compared with the case in which two electron beams are formed in a completely separate manner, the aforementioned configuration is able to form beams with almost the same characteristics in a shorter period of time using fewer power supplies and is able to perform scanning under the same conditions.

[0047]

Secondary electron detector

The secondary electron detector used in the sample checking device must be a high-speed, high-sensitivity detector. In general, a secondary electron detector used for a scanning electron microscope (referred to as SEM hereinafter) is comprised of a scintillator, a optical waveguide (such as an optical fiber cable), and a photomultiplier tube. When a positive high voltage (about 10 kV) is applied to the scintillator, the secondary electrons generated at the part irradiated with an electron beam are attracted to the scintillator to light up the scintillator. The emitted light is guided with the optical waveguide in the photomultiplier tube (light-receiving element), converted into an electronic signal, and then amplified. After the output is further amplified with an amplifier, it is sent to an image forming unit either directly or via an A/D converter. The sample checking device of the present invention requires high checking speed and high checking accuracy. In the aforementioned conventional technology, however, analog signals are optically transmitted without additional processing, so that the noise generated by the light-emitting and light-receiving elements is added to the original analog signals. In other words, the S/N ratio of the secondary electron signal deteriorates for the part transmitted by the optical transmission means. Also, the light-emitting response of the fluorescent plate introduces a delay. Therefore, the high speed and high accuracy required for the sample checking device cannot be achieved.

[0048]

As shown in Figure 4, said secondary electron detector (4) used for sample checking device (1) of the present invention is comprised of semiconductor detector (61) floated at a positive potential generated by high voltage power supply (67), preamplifier (62), A/D converter

(63), optical conversion means (64), transmission means (65), electronic conversion means (66), preamplifier driving power supply (68), A/D converter driving power supply (69), and reverse bias power supply (70). A PIN type semiconductor detector is used as semiconductor detector (61). A PIN type semiconductor detector has a shorter response time than a normal PN semiconductor detector and is able to detect a secondary electron signal with a high frequency of about 100 MHz when a reverse bias is applied by reverse bias voltage power supply (70). Also, said semiconductor detector (61) has very high sensitivity. For example, a current gain of about 2000 can be obtained when the voltage of high voltage power supply (67) is set to 10 kV. A light-emitting element which can convert electronic signals into optical signals is used as optical conversion means (62). An optical fiber cable which can transmit optical signals is used as the transmission means. A light-receiving element which can convert optical signals into electronic signals is used as the electronic conversion means (66). Since the optical fiber cable is made from a highly insulating material, a signal at a high potential can be easily converted into a signal at ground potential. Also, since digital signals are optically transmitted, the signals do not deteriorate at all during optical transmission. As a result, compared with the conventional technology which optically transmits analog signals, the aforementioned method can be used to obtain secondary electron signals with a high S/N ratio, and checking can be performed with high speed and high accuracy.

[0049]

Blocking electrode

When only one electron beam irradiating means is used as in the conventional SEM, the secondary electrons or reflected electrons generated from the sample are detected by a secondary electron detector or reflected electron detector. A pattern image is formed using the detected signal, and the image of the region irradiated with the electron beam is obtained with the aid of the control unit and the display means. In the present application example, however, two electron beams are used together. The signals from two irradiated regions will appear overlapped for a single detector. As a result, the two images cannot be observed independently. Even if a detector is used for each of the electron beam irradiating means, since the secondary electrons or reflected electrons generated under irradiation of one of the electron beams may enter the other detector, the images of the surfaces irradiated with the electron beams cannot be formed correctly. Conventional Examples 5, 7, and 8 disclose some observation examples using multiple electron beam systems. These examples, however, fail to disclose a method which can separate and detect the secondary electrons or reflected electrons generated from different irradiated regions. As described in Conventional Example 6, the irradiation time is divided, and checking is performed synchronously with the irradiation. However, the time needed until comparison is made after

beams are irradiated on the two patterns is almost the same as that in the case when the patterns are irradiated one by one. As a result, the checking time cannot be shortened.

[0050]

In the present invention, as shown in Figure 1, a blocking electrode (5) is arranged between the first electron beam irradiating means (20a) and the second irradiating means (20b) in such a way that the blocking electrode has no electrical contact with sample (2) or objective lenses (25a) and (25b). A negative voltage in the range of -1 V to -50 V with respect to the sample is applied to the blocking electrode by blocking electrode control unit (46).

[0051]

Figure 5 shows the paths of the secondary electrons (28a) and (28b) generated by irradiation of two electron beams (25a) and (25b) to detectors (4a) and (4b). Since blocking electrode (5) has a slightly negative potential with respect to sample (2), the paths of the secondary electrons (28a) and (28b) generated by irradiation of electron beams (25a) and (25b) are curved and point in the directions away from blocking electrode (5). When detectors (4a) and (4b) are positioned opposite blocking electrode (5), the secondary electrons (28a) and (28b) can enter detectors (4a) and (4b), respectively.

[0052]

Consequently, for example, a pattern (54) is present in the scanning region (53a) of the first electron beam (25a) with the original surface shape shown in Figure 6(a), and a pattern (55) is present in the scanning region (53b) of the second electron beam (25b) as shown in Figure 6(b). When the first and second electron beams (25a) and (25b) are irradiated simultaneously, due to the blocking potential, as shown in Figures 6(c) and 6(d), SEM images (53a') and (53b') can be obtained independently in pattern images (54') and (55') corresponding to Figures 6(a) and 6(b), respectively. It therefore becomes possible to observe different regions simultaneously. If the voltage applied to the blocking electrode is too high, the paths of the electron beams will be adversely affected. On the other hand, if the voltage is too low, the secondary electrons or reflected electrons cannot be separated.

[0053]

For example, when sample (2) is at ground potential, a voltage of -20 V is applied to the blocking electrode. In this way, when the two electron beam irradiating means are operated simultaneously, the secondary electrons can be detected independently, and the images formed by the first and second electron beams can be obtained independently. Also, since the electron

beam can be irradiated simultaneously in two regions, the checking time can be reduced by half compared with the conventional method which checks two patterns separately.

[0054]

Although the aforementioned application example associated with the blocking electrode illustrates the case of two electron beam irradiating systems, it is also applicable to a case of four electron beam irradiating systems. Figure 7 is a diagram which shows a sample checking device comprised of four electron beam irradiating systems (75a), (75b), (75c), and (75d) as seen from the side of the electron guns. Detectors (76a), (76b), (76c), and (76d) are used for the electron beam irradiating systems, respectively. Also, blocking electrode (77) is arranged in an appropriate way to prevent the secondary electrons generated from the region irradiated with each of the electron beams from entering other detectors. In this way, four regions can be observed simultaneously. Similarly, the aforementioned method is also applicable to a device having multiple electron beam irradiating systems.

[0055]

Now that the idea about the blocking electrode has been explained, it will be easy for the specialist to design a blocking electrode optimally shaped to capture secondary electrons or reflected electrons at peak efficiency.

[0056]

Optical axis interval adjusting means

The electron beam system including the detectors can be finely adjusted so that the optical axes in the vertical direction can be moved to vary the spacing between the optical axes of the first and second electron beams. The spacing between the optical axes is adjusted so that the same pattern lies in the beam scanning region. It is performed only when the object to be checked is changed. The spacing between the optical axes is an integral number of times the width of the pattern to be checked. In the following, an example of the adjusting means will be explained. The electron guns, lenses, deflectors, and detectors are integrated via an insulating material, etc. The position of the system can be adjusted at a level of 1 μm by using a micrometer head from outside of the vacuum chamber. In this case, to keep the adjusted part to the minimum limit, one of the systems is fixed, and only the other system is adjusted. The adjustment direction is only along the X axis of the beam deflection. At the beginning of the checking, the optical axis adjusting means can be used to approximately match the positions of the images formed by the first and second electron beams. To make it more accurate, the image can be shifted by using a deflector.

[0057]

Sample chamber

Sample stage (10) is in sample chamber (7). XY stage (30) and θ stage (31) are arranged on the sample stage. To reduce the incident energy of the electron beam with respect to the sample, θ stage (31) is electrically insulated from sample (2) so that a negative high voltage can be applied to the sample. A stage position measuring device (48) is used for said sample stage (10) to measure correctly the position of the stage in real time. For example, a laser interferometer can be used. An optical sample height measuring device (47) is also installed to correctly measure the height of the wafer. The device, for example, can measure the height of the surface of the sample in real time from the change in the position of the reflected light obtained by light-receiving means (38') after the light emitted from light-emitting means (38) is obliquely incident on the checking region of the wafer. The focal distances of objective lenses (25a) and (25b) are corrected in a dynamic manner so that SEM images with focuses in the checked region can be formed constantly. Also, the warpage of sample (2) is measured before the sample is irradiated with an electron beam. When the data is corrected to the original level as described above, it becomes unnecessary to perform image adjustment in the checking region.

[0058]

Either of the following two methods can be used to form an electron beam image. In the first method, an electron beam is scanned in two-dimensionally while XY stage (30) and θ stage (31) are kept fixed. In the second method, an electron beam is scanned one-dimensionally while XY stage (30) is moved continuously in the direction perpendicular to the scanning direction. When only a specific place is to be checked, checking can be performed efficiently by keeping XY stage (30) fixed. On the other hand, to inspect a broad area, it is more efficient to use the method in which XY stage (30) is moved continuously.

[0059]

The setting time of the stage will be explained below. For example, when the method for moving the stage is executed using a step-and-repeat system, since the setting time of the stage must be on the order of a ms, the checking time cannot be reduced. Consequently, a continuously moving system is adopted to move the stage at constant speed. In this way, the limitation on the stage checking time can be eliminated. When the stage is moved continuously, it moves during the period of one shot of 12.5 μs, and the irradiating position will change on the sample. Consequently, deflector (23) is used to make the electron beam follow the movement of the stage so that the irradiating position will not change during the period of one shot. Since the irradiating

position of the electron beam moves when viewed from an electron optical system in a static coordinate system, the image formed by objective lens (25) also moves. Deflector (10) is interlocked with deflector (5) to avoid this movement.

[0060]

Image processing unit

Image processing unit (8) is comprised of image memory parts (32) and (33), calculating part (34), and defect evaluation unit (35). The secondary electrons generated under the irradiation of the electron beams are guided into the detectors to form images in image processing unit (8). The obtained pattern images are displayed on monitor (36). The images are stored in memory part (32) or (33) as the images of the places corresponding to the irradiating positions of the electron beam supplied from control unit (9).

[0061]

The SEM images of the two patterns formed and transmitted using the aforementioned method are compared. The SEM image of the checking region of pattern A obtained by the first electron beam (26a) is stored in memory part (32). Then, the image of pattern B obtained by the second electron beam (26b) at the same place is stored in memory part (33) and compared with the image stored in memory part (32) at the same time. After that, the SEM image of the next chip C obtained by the first electron beam (26a) is overwritten and stored in memory part (32) and compared with the image of pattern B stored in memory part (33) at the same time. This operation is repeated to perform comparison checking for all of the patterns over the entire inspection region.

[0062]

In addition to this method, it is also possible to use another method in which the SEM image of a defect-free sample is stored as a reference in memory part (37) in advance. The checking region and checking conditions for the defect-free sample are input from control unit (29) in advance. The defect-free sample is checked based on these data, and the electron image of the desired region is stored in memory part (18). Then, sample (7) is loaded into the checking device and checked using the same method. The obtained electron image is input into memory part (33). Defects can be detected when this image and the SEM image of the defect-free sample stored in memory part (37) are aligned, subjected to image processing, and compared. In this case, a defect-free wafer or chip different from sample (2) or a defect-free part of sample (2) can be used as the defect-free sample.

[0063]

For example, when patterns are formed on sample (2), the lower pattern and the upper pattern might not match. If the comparison objects are circuit patterns in the same wafer or chip, the aforementioned defects occurring in the same way over the entire wafer will be overlooked. When the aforementioned method is adopted, however, since the image of a defect-free sample is stored in advance and is compared with the image of sample (7), the aforementioned defects occurring over the entire wafer can also be detected. For the SEM images stored in memory units (32) and (33), various statistical data including average image density value, statistical data on dispersion, etc., difference between the peripheral pixels, etc., are calculated in calculating part (34) based on the defect evaluation conditions which have already been derived. The signals obtained by processing these data are transferred to defect evaluation unit (35) where they are compared. The difference signals are extracted and categorized by defect and other signals with reference to the defect evaluation conditions which have already been derived and stored.

[0064]

Beam control unit

The operating instructions and operating conditions of each part of the checking device are input/output from control computer (39) via control unit (9). The accelerating voltage for generating the electron beams, the deflection width of the electron beams, the deflecting speed, the interval between the optical axes of the beams, the blocking voltage, the moving speed of the sample stage, the signal input timing of the detectors, and other conditions are input into control computer (39) in advance. Correction signals are generated from the signals of electron gun control power supply (41) used for blanking or controlling the intensity of the electron beams, condenser lens control unit (42) which is used to make sure that the electron beams always irradiate the correct positions, deflector control unit (43), objective lens power supply (45), beam optical axis interval control unit (44), blocking electrode control unit (46), stage position measuring device (47), and sample height measuring device (48). The correction signals are sent to the various parts of the electron beam system.

[0065]

Checking sequence

The device is adjusted before the sample is checked. More specifically, the following adjustments are made before the checking is actually performed: 1. Rotation adjustment of the sample stage performed using an optical microscope, 2. Measurement of the chip position or the distance between chips on a wafer, such as the repetition pitch of memory cells or other repeated patterns, 3. Setting of the blocking voltage, 4. Adjustment of the interval between the optical

axes of the electron beams, and 5. Adjustment of the two electron beams' spatial resolutions, origins, scanning ranges, scanning speeds, etc.

[0066]

1. Rotation adjustment of the sample stage

First, alignment performed using an optical microscope and SEM images will be explained. Sample (2) is set on sample stage (10) and positioned under optical microscope (12). The optical microscope image of sample (2) is observed from monitor (13), and any pattern appearing at the center of the screen is stored. In this case, it is required that the selected pattern also be observed as an SEM image. Then, the optical microscope image is used to perform θ correction with the aid of θ stage (31) such that the pattern of sample (2) is parallel or perpendicular to the moving direction of the stage. During the θ correction, the optical image of the pattern of sample (2) at a certain position is retrieved and stored after it is marked at any given place on the screen from monitor (13). Then, XY stage (30) is moved in the x or y direction by a distance of several patterns, and the optical image of the same pattern in the chip is retrieved and compared with the image, which is stored in memory part (32) in image processing unit (8) beforehand, to calculate the deviation from the marked place. θ is calculated from the moving distance of XY stage (30) in the x or y direction and the displacement of the image to correct θ stage (31). The operation is repeated several times to keep the rotational angle within a prescribed range.

[0067]

2. Measurement of the sample conditions

The optical microscope image is used to observe the pattern of sample (2), and the chip position or the distance between chips on a wafer, such as the repetition pitch of memory cells or other repeated patterns, is measured beforehand. The value is input into control computer (39). The chip to be checked on the wafer and the region to be checked in the chip are set from the optical microscope image on monitor (13). The optical microscope image can be observed at relatively low magnification. Also, the sample can be observed up to the substrate if the surface of semiconductor device (2) is covered with a transparent film, such as a silicon oxide film. Consequently, the layout of the circuit patterns in the chip can be observed easily, and the checking region can be set easily.

[0068]

Then, said sample (2) is moved to a place below electron beam system (3). An electron beam is incident at a place which is presumed to be the same location on the same sample (2) to

obtain an SEM image. At that time, the aforementioned pattern is moved into the region which is irradiated by one shot of the electron beam. XY stage (30) and θ stage (31) are moved appropriately so that the aforementioned pattern marked at the same position as the image position in the optical microscope also appears in the SEM image. In this way, it is possible to match the electron beam's irradiating position with the observing position of the optical microscope before the checking is started, and the electron beam's irradiating position can be corrected. For the SEM image, the same operation as that performed using the optical microscope is carried out. In this way, optical microscope (12) is used to easily confirm or adjust the observation position, adjust the position of the electron beam's irradiating position, and perform rotation correction by a certain degree. Then, an SEM image which has a higher resolution than the optical image and can be input at a high magnification is used to perform precise rotation correction.

[0069]

Also, the SEM image is used to observe, confirm, and correct the checking region or the same pattern region at high magnification and with high accuracy. However, if the surface or a part of sample (7) is made of an insulating material, the sample will be charged when irradiated with an electron beam, and it might not be able to check the sample when the electron beam is irradiated just once. In this case, the beam irradiation used for obtaining the aforementioned measuring conditions can be performed in a region in which actual checking will not be performed and at a selected place with the same pattern as the region to be checked.

[0070]

After the checking conditions are set, an image is obtained from a part of the checking region of sample (7) under exactly the same conditions as the actual checking conditions. Information regarding brightness of the image, which depends on the material and shape as well as the brightness range, are calculated and stored in a table. The conditions for evaluating the defects to be checked are determined with reference to the table.

[0071]

Checking is started after the checking region and defect evaluation conditions are set using the aforementioned method. During the checking, XY stage (30) loaded with sample (2) is moved continuously at constant speed in the X direction. During that period, an electron beam is irradiated at the same place on the sample for a certain period of time (50 μs or longer in the present application example) during one shot. Since the stage is moved continuously, deflector (23) is used to make the electron beam follow the stage.

[0072]

Stage position measuring device (47), sample height measuring device (48), etc., arranged on sample stage (10) are monitored in the region or at the position irradiated by the electron beam. The details of the information of these parts are sent to control computer (39), and the measured deviation is corrected using electron beam control unit (40). In this way, correct alignment required for comparison checking can be performed at low cost and at high speed and high accuracy.

[0073]

3. Setting the blocking voltage

Different patterns are scanned simultaneously with the first and second electron beams when the potential of the blocking electrode is the same as that of the sample. The secondary electrons or reflected electrons obtained from the irradiated parts are detected with the detectors to form images. In this case, the two images formed by the two electron beams are almost identical. Then, a negative potential with respect to the sample potential is gradually applied to the blocking electrode while the two images are being observed. When the potential of the blocking electrode is, e.g., -20 V, the two images are completely separated, and different patterns are observed. In this state, the secondary electrons or reflected electrons obtained by irradiation of the two electron beams can be collected independently. When a voltage higher than the aforementioned level is applied, the paths of the electron beams will be bent and will cause problems in observation. Preferably, the applied voltage is set in the range of -1 V to -50 V with respect to the sample potential. The potential of the blocking electrode is maintained at that level thereafter.

[0074]

4. Adjustment of the interval between the optical axes of the electron beams

Then, the interval between the optical axes of the electron beams is adjusted. Electron beam irradiating means (20b) is moved by a mechanical coarse adjustment means constituted with optical axis interval adjusting means (6) (such as an encoder) according to the dimensions of the repeated patterns measured by optical microscope (12) beforehand. In this case, only one beam irradiating means is moved, while the other is fixed. To perform more accurate adjustment, the repeated patterns on the sample are observed simultaneously with the two electron beams.

[0075]

When the patterns are observed simultaneously with the two electron beams, the accelerating voltages applied to the two beam systems, the lens voltages, the deflecting voltages, etc. are set at the same respective levels, to make sure that the beams reaching the sample have the same properties. Corrections are performed by means of image shifting so that the characteristic points of the patterns are at the same positions in the two images.

[0076]

5. Comparison with the reference pattern

The checking region and checking conditions for a defect-free sample are input from image processing unit (8) beforehand. The defect-free sample is checked based on the input data, and the SEM image of a prescribed region is stored in memory part (37). Then, sample (2) is checked. The SEM images are input into memory parts (32) and (33). The images and the SEM image of the defect-free sample stored in said memory part (37) are subjected to alignment, image processings, and comparison to detect the defects. In this case, a defective-free wafer or chip different from sample (2) or a defect-free part of sample (2) can be used as the defect-free sample. For example, when patterns are formed on sample (2), mismatching might occur between the lower pattern and the upper pattern. If the comparison objects are circuit patterns in the same wafer or chip, the aforementioned defects occurring in the same way over the entire wafer will be overlooked. When the aforementioned method is adopted, however, since an image of a defect-free sample is stored in advance and is compared with the image of sample (2), the aforementioned defects occurring over the entire wafer can also be detected. For the SEM images stored in memory units (32) and (33), various statistical data including an average of the image density value, statistical data on dispersion, etc., difference between the peripheral pixels, etc., are calculated in calculating part (34) based on the defect evaluation conditions which have already been derived. The signals obtained by processing these data are transferred to defect evaluation unit (35) where they are compared. The difference signals are extracted and categorized by defect and other signals with reference to the defect evaluation conditions which have already been derived and stored.

[0077]

Images formed using the secondary electrons or reflected electrons generated from sample (2) can be compared and checked using the sample checking device and the sample checking method explained thus far. In this way, the sample can be checked at a higher speed than that of the conventional sample checking device which uses electron beams.

[0078]

Application Example 2

In the present application example, the semiconductor device on a wafer is checked for defects using sample checking devices (1) disclosed in said Application Example 1. As shown in Figure 8(a), 128 semiconductor device chips (81) are loaded on wafer (80). The interval between the optical axes of two electron beams is 4 times the width of a device chip. Since the width of the device can be found from the design diagram of the semiconductor device, the interval can be coarsely adjusted. Since the coarse adjustment is a mechanical adjustment, its accuracy is limited to 1 μm or smaller. For a more accurate adjustment, image shifting is performed with a deflector while observing the SEM image formed by the first electron beam. The images formed by the first and second electron beams can be used constantly to observe the same pattern of four devices in the width direction.

[0079]

By using the aforementioned preset method and checking method, the first electron beam is moved from A01 to A02 and all the way to A72 of chip No. 83 in the checking sequence (84), and the second electron beam is used to perform checking from chip No. B01 to B02 and all the way to B72. In this way, checking of one wafer is completed. The two electron beams are scanned at an interval of 4 times the chip width constantly kept between them. Also, for example, as shown in Figure 8(b), scanning of the electron beam on chip (81) is performed from origin (a) to end point (z) (symbol (85) represents the path of the electron beam) in a single pass.

[0080]

When checking chips A01 and B01, there is actually a chip at B01, but there is no chip at A01. In this case, the operation for obtaining the pattern image by means of beam scanning is performed at B01. On the other hand, beam scanning is also performed at A01, but the image signal is not input into the calculating unit. Instead, the defect-free pattern stored in the image memory part is compared with the pattern obtained from B01 in the calculating unit. The situation is the same when checking A18 and B18. On the other hand, when there is a chip at A but no chip at B, for example, when checking A72 and B72, the comparison with the defect-free pattern is carried out in the same way. In the case of the wafer shown in Figure 8(a), for 16 groups of the 72 groups of A and B on the wafer, only one pattern is compared with the defect-free pattern. For the other 56 groups, the patterns are compared between chips A and B. When the comparison checking is carried out in the aforementioned sequence, the time needed for checking all of the chips on the wafer using the method of the present invention in which two electron beams are irradiated simultaneously is 72t. Compared with the time 128t (where t

represents the time needed for checking one chip) required for the conventional method in which the chips are checked with an electron beam one by one, the checking time can be shortened by about 48.3%.

[0081]

In the present application example, the interval between the two electron beams is equal to the total width of four chips. The present invention, however, is not limited to this example. It is also possible to set the interval as the total width of two chips. In this case, the time needed for checking all of the chips is the same as that of the aforementioned case when the interval is equal to the total width of four chips.

[0082]

Also, two electron beams are used in the present application example. However, it is also possible to use three or more electron beams for the comparison checking. For example, when the same wafer is checked using four electron beam systems which are arranged at an interval equal to the total width of two chips, the time required for checking the entire wafer is 36t, which is shortened by about 71.9% compared with that of the conventional method.

[0083]

Application Example 3

Application Example 3 discloses a magnetic head checking device which is used to check magnetic heads used for computer's hard disk, etc.

[0084]

First, the manufacturing process of magnetic heads will be explained briefly. As shown in Figure 9(a), sensors, coils, magnetic cores, etc. are formed on a ceramic circular substrate (9) with a diameter of, e.g., 5 in. For example, a total of 10,000 elements (91) are formed regularly in a matrix of 50 columns and 200 rows on circular substrate (90). Then, said circular substrate (90) is cut into strip-shaped substrates (93) (to a length of 2 in) with a disk-shaped cutting blade (arrows (94) in the figure indicate the cutting directions). The floating surface (perpendicular to the surface of the circular substrate) of each cut strip-shaped substrate (93) is polished. After that, a recessed part (94) for maintaining head flotation is formed as shown in Figure 9(b). Finally, strip-shaped substrate (93) is cut with cutting blade (96) and separated into individual magnetic head chips (95).

[0085]

In recent years, in order to increase the recording density, the two ends of the recording track are trimmed to narrow the effective track width for each magnetic head chip (95) on strip-shaped substrate (93) before it is cut and separated. Figure 10 shows this operation in simplified form. As shown in Figure 10(a), the width W of recording head (101) formed on floating surface (100) of a magnetic head is in the range of 1-2 μm. The width W of recording head (101) must be reduced in order to increase the recording density. Narrow recording heads, however, are difficult to form. In this case, the two ends of recording head (101) are scanned with FIB (focused ion beam) to form recessed parts (102) and (102'). In this way, the width W' of the recording head can be essentially reduced to 0.5-0.8 μm. As a result, the recording density can be increased.

[0086]

There are various trimming methods. For example, the recording head can be trimmed using a laser or by means of sputtering by using ion beams. However, since the track width W' varies due to the deviation of the irradiated beam, an operation for checking the defective products is required after the trimming operation but before the strip-shaped substrate is cut into individual magnetic head chips. The sample checking method of the present invention can be used for this operation.

[0087]

In the following, the schematic configuration of magnetic head checking device (110) of the present invention will be explained with reference to Figure 11. Said magnetic head checking device (110) has multiple groups of electron beam systems. In this case, however, a device with a two-electron-beam system will be explained for the sake of clarity.

[0088]

The electron beam system comprises of first and second electron beam irradiating means (103) and (103'), which are used to irradiate electron beams on the magnetic head surface, as well as detectors (104) and (104') used for detecting the secondary electrons or reflected electrons generated from the regions irradiated with the electron beams. The first and second electron beam irradiating means have the same configuration as that of the electron beam system of the sample checking device disclosed in Application Example 1. Each electron beam irradiating means is comprised of an electron gun, extracting electrode, diaphragm, condenser lens, scanning deflector, deflector for blanking, and electrostatic objective lens. Therefore, its explanation is omitted in this case. Sample stage (105) is used to carry strip-shaped substrates

(93) and (93') and is able to move continuously at least one of the aforementioned samples during the period when the first or second electron beam is irradiated on the aforementioned sample. The sample stage is equipped with an XY stage, rotary stage, optical height measuring device, length measuring device for position monitoring, etc. These parts, however, are omitted from the figure because they are identical to those described in Application Example 1. In particular, in order to arrange the magnetic heads regularly in the form of a strip-shaped substrate and to correctly cut the strip-shaped substrates, grooves for sinking strip-shaped substrates (93) and (93') slightly are formed on sample stage (105). Said strip-shaped substrates (93) and (93') can be semi-fixed when they are set in the grooves. 1250 magnetic head chips can be checked by loading 50 strip-shaped substrates on sample stage (105) at one time. After the checked strip-shaped substrates (93) and (93') are automatically unloaded from sample stage (105), the strip-shaped substrates to be checked next are loaded. Blocking electrode (107) is between electron beam irradiating means (103) and (103') and is set at a position which has no electric contact with strip-shaped substrates (93), (93') or sample stage (105). The secondary electrons or reflected electrons generated from the regions irradiated with the first and second electron beams are detected independently. The voltage applied to blocking electrode (107) is set to a negative potential in the range of -1 V to -50 V with respect to sample stage (105). This voltage is high enough to make the secondary electrons fly toward detectors (104) and (104') without affecting the paths of the electron beams. The image processing unit, beam control unit, etc., are omitted from the figure because they are the same as those described in Application Example 1.

[0089]

As shown in Figure 12, it is also possible to place the strip-shaped substrates parallel to each other and perpendicular to the main feeding direction (direction of axis Y in the figure) of sample stage (105) in magnetic head checking device (110'). Multiple strip-shaped substrates (93) are loaded on a sample stocker (115) so that the samples can be collected and exchanged easily for each batch to be inspected. In the example shown in Figure 12, two sample stockers (115) are set on sample stage (105). Blocking electrode (107) is between electron beam irradiating means (103) and (103') and is set at a position which has no electric contact with strip-shaped substrates (93), (93') or sample stage (105). The appearance of each head is checked. The stage is fed in such a way that the samples are moved one row at a time along the Y axis and one head at a time along the X axis. The checking time for each head is 1 s including the time for stage movement, image processing, etc. Consequently, it will take 1.4 h to complete the checking of 10,000 heads formed on one circular substrate.

[0090]

Two groups of electron beam systems are used in the aforementioned application example. However, it is also possible to use a three-electron-beam system. The electron beam irradiating means are arranged in such a way that the points of intersections of their optical axes and the surface of the sample are on the same straight line. It is possible to arrange multiple strip-shaped substrates loaded with the magnetic heads parallel to each other on the sample stage corresponding to the intervals between the electron beams. The strip-shaped substrates can move in the longitudinal direction and in the direction perpendicular to the straight line that passes through the aforementioned points of intersection. Or, since grooves that sink at least part of the strip-shaped substrates are formed on the sample stage so that the strip-shaped substrates are movable in the longitudinal direction, it is possible to avoid displacement except in the longitudinal direction. It is also possible to only move the strip-shaped substrates while keeping the sample stage fixed. In this way, rows of magnetic heads can be moved one by one and can be checked efficiently.

[0091]

Since there are sample stockers used for holding multiple strip-shaped substrates in the sample chamber, a large number of magnetic heads can be moved to the checking positions (in the regions irradiated by the electron beams) in the vacuum chamber without being exposed to air.

[0092]

It is also possible to use more than two electron beam irradiating systems in the aforementioned method. Blocking electrodes are used to prevent the secondary electrons or reflected electrons from entering a wrong detector in the multiple electron beam systems. The detectors are arranged in such a way that it is difficult for interference to occur. The width of the head is measured, and the shape defects are checked.

[0093]

<u>Application Example 4</u>

Said Application Example 3 disclosed a sample checking device which is used to check the appearance of magnetic heads by combining multiple groups of electron beam irradiating systems and detectors corresponding to these electron beam irradiating systems. The present application example, however, discloses a device which uses ion beams instead of electron beams to process samples by simultaneously irradiating the ion beams on different heads. In particular, the present application example pertains to a magnetic head processing device for

trimming recording heads. When an FIB with a beam diameter in the range of tens of nm to hundreds of nm is used as the electron beam to scan the a desired region of a sample, a recessed shape corresponding to the scanned region can be formed by means of sputtering. Also, when an FIB is irradiated at the same time that a metallic gas or reactive gas is introduced, a deposited film or an accelerated etching hole can be formed. The processing method is called the FIB processing method.

[0094]

In a conventional FIB device, since only one ion beam irradiating device is used, the processing time becomes long when processing a lot of devices. When multiple FIB irradiating systems are used, the secondary electrons generated from the multiple irradiated regions might enter the wrong detector. This is a problem. To solve this problem, secondary electron blocking electrodes are arranged between the FIB irradiating systems.

[0095]

As shown in Figure 13, in magnetic head processing device (120), FIB is used as the ion beam, and four beam irradiating means are used. This diagram is a top view that clearly illustrates the positional relationship between the secondary electron blocking electrode and the detector. (121a), (12b), (121c), and (121d) represent FIB irradiating means. (122a), (122b), (122c), and (122d) represent the corresponding secondary electron detectors. Blocking electrodes (123a), (123b), (123c), and (123d) are used to prevent secondary electrons from entering the adjacent secondary electron detectors. Strip-shaped substrates (93) loaded with the magnetic heads (95) explained in Application Example 3 are arranged parallel to each other corresponding to the FIB irradiating systems on sample stage (124) which can move in directions XYZθ. After sample stage (124) is subjected to Z and θ correction, it moves following stage track (127). Also, FIB irradiating systems (121a), (121b), (121c), and (121d) are operated at the same time to process magnetic heads (95) one by one.

[0096]

The processing places, for example, are the two ends of each recording track shown in Figure 10. A recessed part (102) is formed under FIB irradiation. In this way, the recording tracks are trimmed. When four FIBs are irradiated at the same time, since simultaneous processing is carried out, the processing speed is such that the trimming processing can be completed in 1/4 of the time needed by a conventional FIB processing device which uses a one-beam system. Also, the secondary electrons generated by the parallel FIB irradiating systems can be prevented from entering adjacent detectors with the aid of secondary electron blocking

electrodes (123a), (123b), (123c), and (123d). The shapes of the various processed regions can be observed independently.

[0097]

The details of the present invention have been explained with reference to the aforementioned application examples. However, the present invention is not limited to these application examples. Various modifications can be made. For example, the devices disclosed in the aforementioned application examples are used to check semiconductor wafers or magnetic heads or process magnetic heads. However, the present invention can also be applied to checking of lithographic masks, micromachine manufacturing devices, etc.

[0098]

Effect of the invention

According to the present invention, patterns can be checked with electron-beam-based systems at a significantly higher speed.

Brief description of the figures

Figure 1 is a block diagram illustrating an application example of the sample checking device disclosed in the present invention.

Figure 2 is a diagram explaining the problems occurring when electron beams are irradiated simultaneously using the two conventional electron beam systems.

Figure 3 is a diagram explaining the problems of an image obtained when electron beams are irradiated simultaneously using the two conventional electron beam systems.

Figure 4 is a block diagram illustrating the configuration of the checking unit in an application example of the sample checking device disclosed in the present invention.

Figure 5 is a diagram explaining the effects of the blocking electrode in an application example of the sample checking device disclosed in the present invention.

Figure 6 is a diagram explaining the effects of the blocking electrode in an application example of the sample checking device disclosed in the present invention.

Figure 7 is a top view illustrating an arrangement example of blocking electrodes in an example which uses four electron beam irradiating systems.

Figure 8 is a diagram explaining the checking sequence in the sample checking method disclosed in the present invention.

Figure 9 is a diagram illustrating the process of manufacturing magnetic heads.

Figure 10 is a diagram explaining a method for processing magnetic heads.

Figure 11 is a schematic diagram explaining the configuration of an application example of the magnetic head checking device disclosed in the present invention.

Figure 12 is a schematic diagram explaining the configuration of another application example of the magnetic head checking device disclosed in the present invention.

Figure 13 is a schematic diagram explaining the configuration of an application example of the magnetic head processing device disclosed in the present invention.

Brief description of the reference numerals

1 Sample checking device

2 Sample

3 Electron beam system

4a, 4b, 76a, 76b, 76c, 76d, 122a, 122b, 122c, 122d Detectors

5, 77 Blocking electrodes

6 Optical axis interval adjusting means

7 Sample chamber

8 Image processing unit

9 Control unit

10 Sample stage

11 Vacuum chamber

20a, 20b, 75a, 75b, 75c, 75d, 103, 103' Electron beam irradiating means

28a, 28b Secondary electron

81 Device chip

95 Magnetic head chip

101 Recording head

121a, 121b, 121c, 121d Ion beam irradiating means

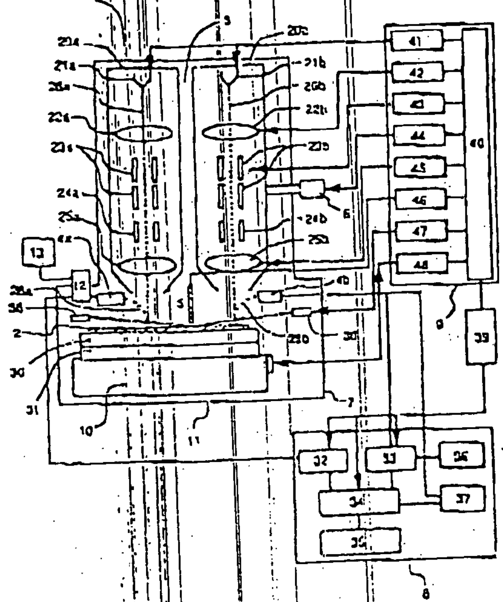


Figure 1

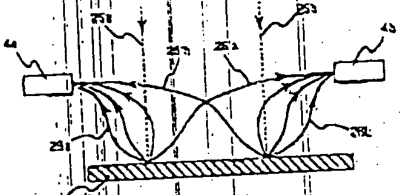


Figure 2

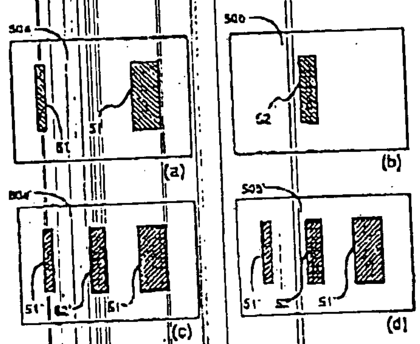
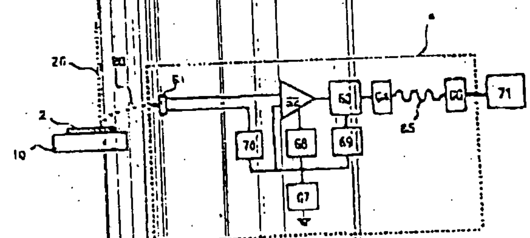


Figure 3



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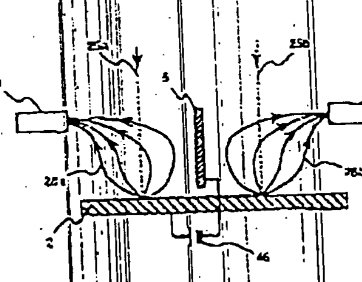
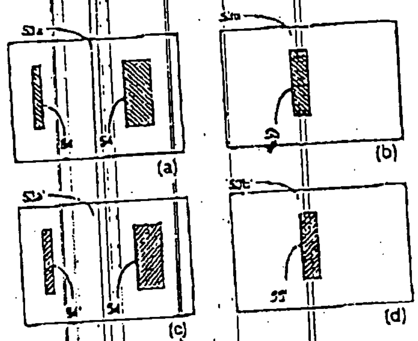


Figure 5



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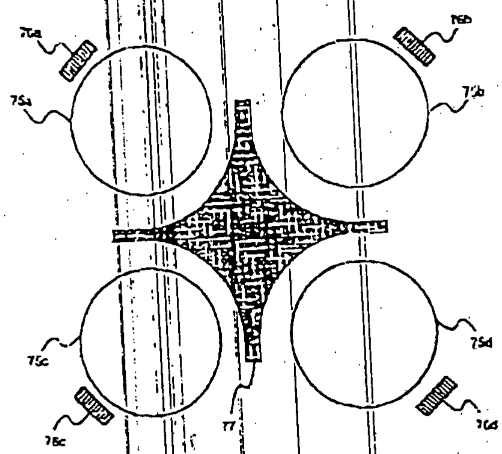
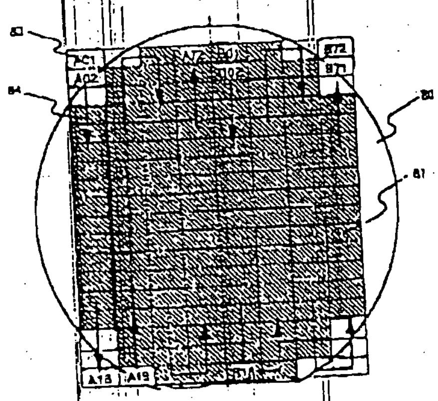


Figure 7

(a)



(b)

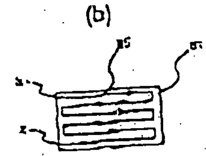


Figure 8

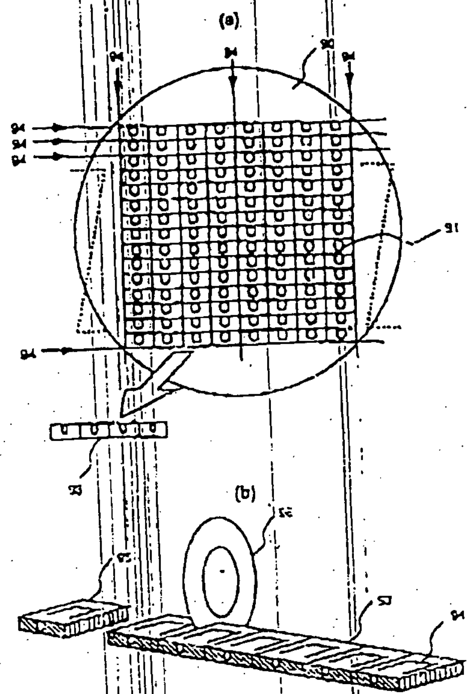


Figure 9

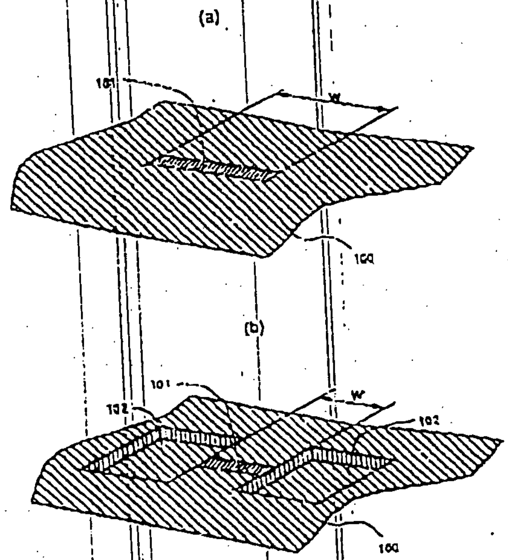


Figure 10

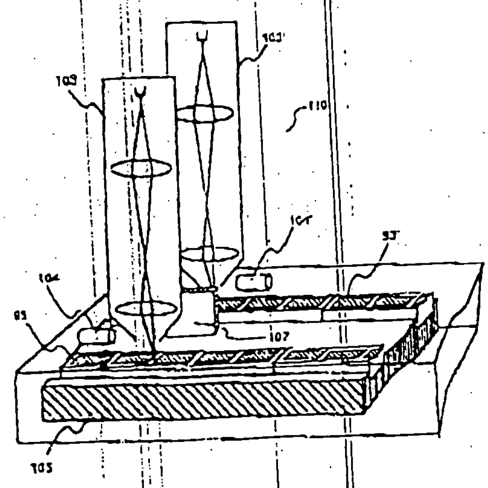


Figure 11

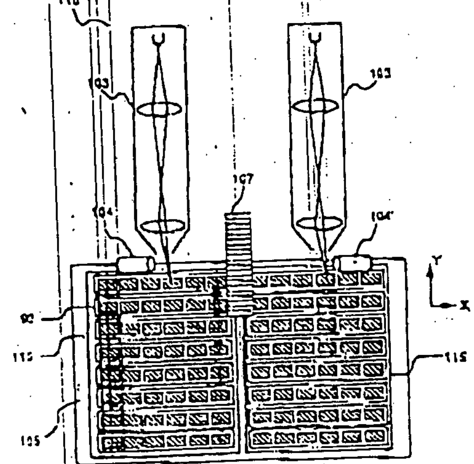


Figure 12

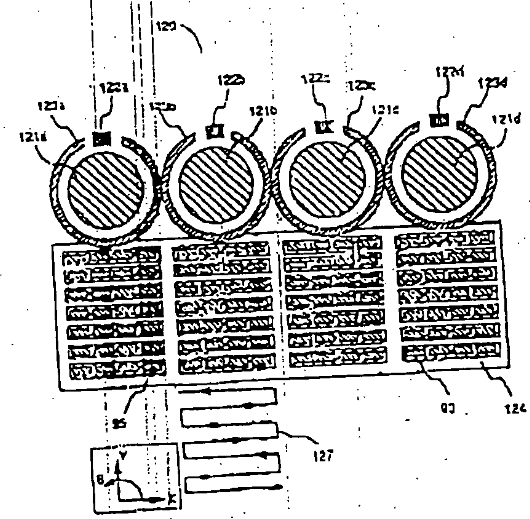


Figure 13